Wisconsin's Fish Contaminant Monitoring and Advisory Program: 1970-2010

Candy S. Schrank[1]
Wisconsin Department of Natural Resources
101 S Webster Street
Madison WI 53707

Abstract. - The fish consumption advisory program is an important, ongoing, joint Departments of Health Services (DHS) and Natural Resources (DNR) program that generates interest locally and globally from people who are interested and concerned about the quality of the fish in Wisconsin's waters (including people who eat sportfish or commercially harvested fish, those who rely on a tourism-based business, and those who are concerned about wildlife health). The DNR collects and analyzes samples of fish tissue from Wisconsin's inland waters and the Great Lakes for a variety of contaminants. This information is needed to protect the health of people who eat fish. Along with the DHS, the DNR uses advisory protocols to determine appropriate fish consumption advice. Fish contaminant data is also used to evaluate clean-up and pollution control efforts designed to protect human health, fish, and wildlife that depend on water-based food chains. This report provides a brief overview of Wisconsin's fish contaminant monitoring and consumption advisory programs.

The objectives of the fish contaminant monitoring and advisory program include, but are not limited to, protection of fish consumers, environmental protection, and resource management:

Protection of health of people who eat fish
- Determine levels of bioaccumulative contaminants in the edible portions of fish and compare these levels to health guidelines as determined by DHS
- Issue fish consumption advisories for species and sizes of fish from areas where the concentrations of chemicals in fillets exceed the health advisory levels.
- Evaluate contaminant levels in commercial fish and share with interested parties. In the past, commercial fishing bans were issued where fish of a given species exceed FDA tolerance levels from a particular waterbody.

Environmental Protection
- Determine if water quality standards are being met.
- Identify impaired waters.
- Identify causes and sources of water quality impairments, including (but not limited to) contaminated sediments, industrial discharge, landfills and groundwater contamination.
- Evaluate program effectiveness: fish tissue monitoring provides information to evaluate remediation of sediments and controls placed on discharges and emissions.
- Evaluate the effects of past/present use of pesticides.

Resource Management
- Evaluate the health impact of contaminants on piscivorous fish and wildlife by analyzing forage fish consumed by these species.

History of the Program: 1970-2010

In Wisconsin, we know more about pollutants that bioaccumulate in fish and associated health concerns than when fish contaminant monitoring began and the first advisories were issued. The number of sites in Wisconsin with fish consumption advice grew through the years as more locations in the state were tested and waters with contaminated fish were found but also changed as protocols for determining appropriate health advice evolved. Table 1 shows the number of sites where fish contaminants have been tested for contaminants and the number of samples by year along with a tally of the number of sites with consumption advisories since 1970. Figure 1 shows the location of sites sampled for fish contaminants at least once in two time periods: a) 1970-1999 and b) 2000-2010.

PCBs

Wisconsin began testing fish for PCBs in 1970. based on early correspondence, DHS and DNR began deliberations in the early 1970s on what levels of PCBs in fish warranted concern. Wisconsin's Health Officer concluded in 1971 that 5 ppm total PCBs was a prudent public health action level. At the same time, the U.S. Food and Drug Administration (FDA) set the tolerance level at 5 ppm total PCBs. Tolerance levels are established by the FDA to regulate

interstate commerce of fish and reflected to some degree economic impacts of commercial fishing bans. DNR began including the Health Officer's advice for fish consumers in the 1976 fishing regulations. The 1977 advice recommended no more than 1 meal per week of carp, trout and salmon over 20" from Green Bay and Lake Michigan; carp from the lower Fox River; catfish, carp, and white bass from parts of the Mississippi River; and carp from the upper Fox River. FDA's tolerance level was reduced to 2 ppm in 1984. These early advisories were based on the percentage of samples from a lake or river segment that exceeded the tolerance levels. Wisconsin used these tolerance values for determining advice until 1996. The advice varied through the years but included "do not eat" advice for some species at a growing number of sites reaching 24 in 1996.

Wisconsin and some Great Lakes states began determining PCB-based advisories according to the "*Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory*" (referred to as "*The Great Lakes PCB Protocol*"; Anderson, et. al., 1993) in 1997. This protocol was presented to the Natural Resources Board as an informational item in May 1995. The consensus protocol was developed after several years of effort by the Great Lakes consortium, comprised of human health and fish contaminant experts from the Great Lakes states. This effort was undertaken to ensure that fish consumption advice reflected new information on how PCBs affect human health, characteristics of anglers and fish consumers in the Great Lakes region, and used consistent data and communication methods for the shared Great Lakes. Main goals of the new protocol were to better protect human health and to improve comprehension of advisories by the public by having one set of advice issued by states bordering each of the Great Lakes. The number of Wisconsin's surface waters with PCB-based advisories has remained fairly constant since the *Great Lakes PCB Protocol* was implemented in 1997 to 2010 (Table 1).

Mercury

DNR began monitoring mercury residues in fish in 1970 following Swedish and Canadian reports of mercury contamination in fish (Kleinert and Degurse, 1971, *Mercury Levels in Fish from Selected Wisconsin Waters,* Research Report 73, DNR, Madison, WI). Highest concentrations were found in fish from several rivers at locations below paper mills where mercury-based slimicides were used and below a

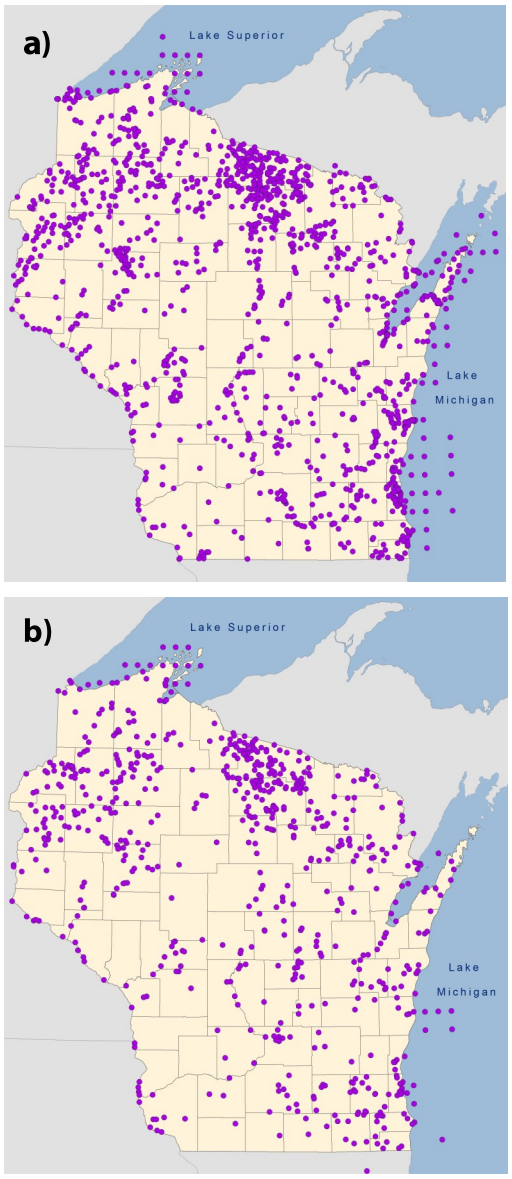

Figure 1. Locations from which fish were sampled at least once for contaminant analysis.
a) 1970-1999 and b) 2000-2010

mercury cell chlor-alkali plant. Soon, orders were issued to stop the discharge of mercury. Monitoring of mercury residues in fish continued and Wisconsin began issuing mercury-based advisories in 1985 after DNR monitoring found higher levels of mercury in predator species of fish from northern lakes remote from any direct discharger or emitter of mercury. Different recommendations are provided for women of childbearing age and children versus men and older women for waters based on mercury concentrations found in fish from sampled waters. Advice was 'unlimited', '26 to 13 meals per year', '1 meal per month' or 'do not eat' depending the gender and age of the person eating fish and on the mercury concentration in the fish ranging from 0.5 µg/g to 1 µg/g (*Wisconsin Mercury-Fish*

Consumption Health Advisory, Anderson and Olson, 1986). Eventually, advice was provided for 331 locations due to mercury using the 1986 mercury protocol.

In 2001, Wisconsin adopted a statewide advisory after the National Research Council and EPA determined there was a need to better protect fetuses and young children from mercury exposure. The statewide advice (Table 2) is designed to prevent ingestion of mercury above a safe reference dose based on typical mercury levels found statewide in Wisconsin fish. In addition, another goal of the statewide advice was to provide a simple message that frequent fish eaters could easily remember. The statewide advice includes advice for all people but differs by the age and gender of the person. It also varies by fish species ranging from 'unlimited' to 'do not eat'. Figure 2 shows the range of mercury concentrations found in species with sample numbers greater than 50 for the collection period 2000-2010. Mercury concentrations vary between species, waterbodies, and can vary with the size or age of the fish. Predator type species have the highest concentrations compared to other species that feed lower on the aquatic food chain. The statewide advisory replaced the need for specific advisories on many of the listed waters. The tally of advisory locations shown in Table 1 for years 2001 is only of those location with advisory exceptions to the statewide advice that was adopted in 2001.

In 2007, an addendum to *The Great Lakes PCB Protocol* mentioned in the previous section was completed by the Great Lakes Fish Advisory Consortium to address mercury-based advice for the sensitive population (women of childbearing age and children under age 15). Whereas the goal of *The Great Lakes PCB Protocol* focused on developing the same PCB-based advice for open-water species common to each of the Great Lakes, the goal of the mercury addendum was to address different inland waters (most not shared between states) that are affected by the same ubiquitous pollutant. Therefore, while the mercury addendum provides consistent methods for advisory determination, differences in actual advice may exist due to differences in species occurrence, contaminant concentrations, and other factors including implementation issues and differences in risk evaluations.

The mercury addendum confirmed the use of the U.S. EPA reference dose (RfD) as the basis for advice for women of childbearing age and children under age 15. Future work of the Great

Table 1. Monitoring summary by year

Year(s)	Sites Sampled**	Samples Collected **	No. of Reaches or Waters with Specific Advisories
Before 1980	234	3,003	7/0
1980 - 1989	969	11,124	24/161
1990 - 1996	564	8,965	24/233
Great Lakes uniform PCB protocol adopted			
1997 - 2000	308	3,444	59/331
Statewide mercury advice adopted***			
2001	118	1,000	20/92
2002 - 2009	576	7,244	49/92 - 49/99
2010	54*	620*	49/102
2011	84*	790*	44/105
Total	1,710*	37,261**	

*Samples still being tallied, total number as of February 2012
**Total number of sites includes samples collected/analyzed by collaborators (GLIFWC and others) but does not include duplicate visits to a site
***Statewide general mercury advice applied to all inland waters replaces some site-specific mercury advisories.

Table 2. General state-wide fish consumption advisory (2001-present, modified in 2007)

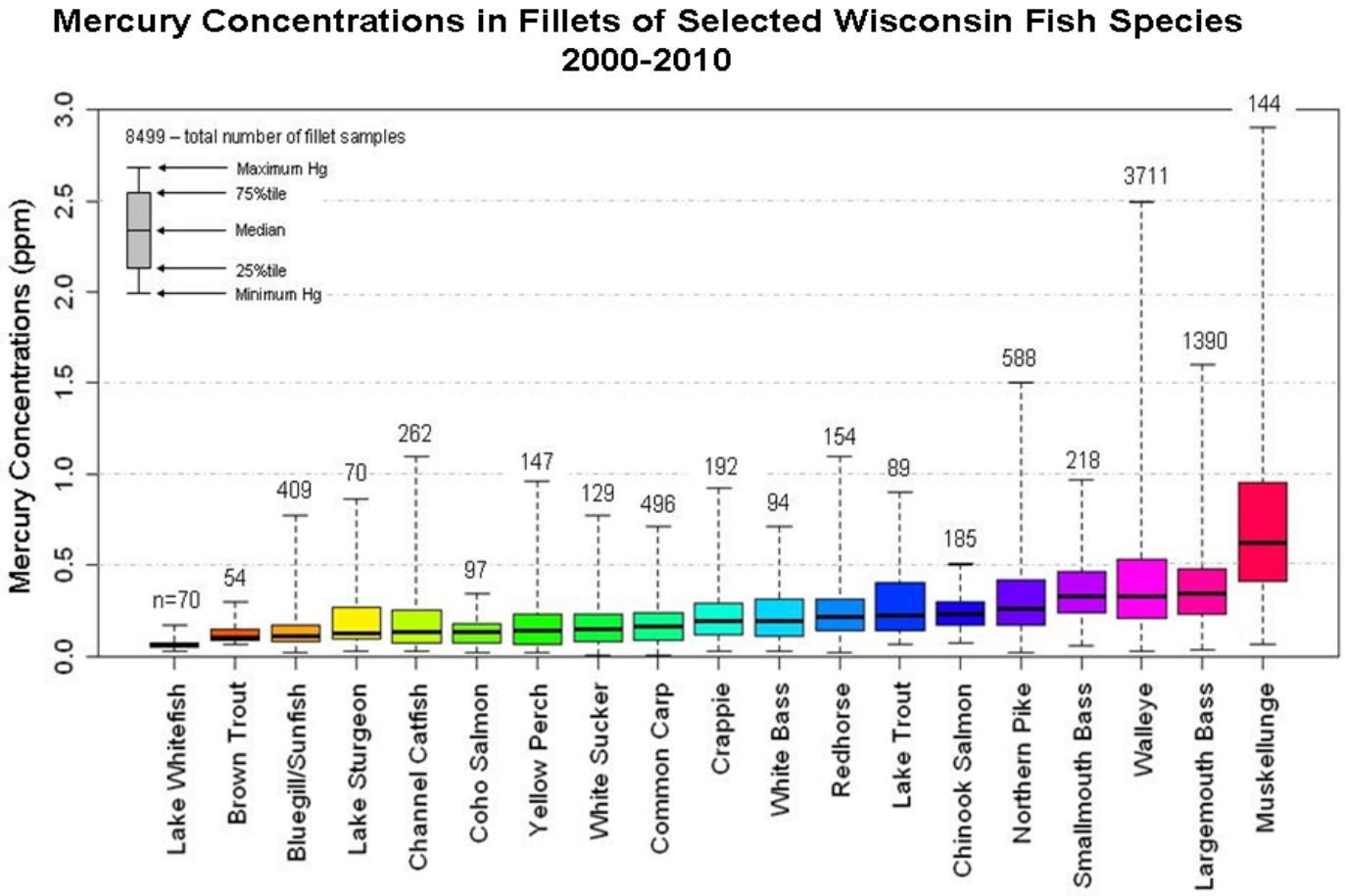

Figure 2. Mercury concentrations in Wisconsin fish species that have had >50 fillets analyzed.

Lake states may address mercury-based advice for other people.

Other Chemicals

PCBs and mercury are responsible for most of the advisories for Wisconsin waters although some species from a few waterbodies also have advice due to dioxin and furan congeners and perfluorooctane sulfonate (PFOS). Several chloro-organic pesticides also accumulate in fish (e.g. DDT, chlordane, dieldrin, aldrin, toxaphene, and others) but have declined after use was restricted or banned. Monitoring of some of these chemicals continues on a limited basis and are found in some species at very low levels compared to concentrations found in the 1970s.

Protocols for issuing dioxin/furan based consumption advice also evolved over time. Prior to the mid-1990s, only 2,3,7,8-TCDD (dioxin) and 2,3,7,8-TCDF (furan) were quantified in fish due to limitations of analytical techniques and knowledge about other dioxin and furan congeners. In 1983, DNR suspended commercial fishing of carp from sections of the Wisconsin River due to dioxin and people were advised not to eat any carp from the Petenwell and Castle Rock Flowages. Consumption advice was issued when 2,3,7,8-TCDD exceeded 50 ppt and later 25 ppt 2,3,7,8-TCDD. Wisconsin began using 10 ppt dioxin total toxic equivalent concentration (TEQ) as the tissue concentration to issue 'do not eat' advice in 1997 when congener analysis and toxicity equivalency factors (TEFs) became available for 7 dioxin and 10 furan 2,3,7,8-TCCD-like congeners. TEQs are calculated by summing the product of the 2,3,7,8-substituted dioxin and furan congener concentrations and the associated toxicity equivalency factor (EPA TEFs were used until 2004, WHO TEFs used 2005-present) for human health.

Fish consumption advice was first issued due to perflourooctane sulfonate (PFOS) in some species of fish from the Mississippi River in 2007. The advice was issued using an RfD developed by Minnesota (0.08 µg/kg-day) after perfluorochemicals (PFCs) were found in groundwater, surface water, and fish (Health Risk Limits for Perfluorochemicals, January 15, 2008, Minnesota Department of Health. A reference dose is the estimated daily dose of a

substance that can be consumed safely over a lifetime.

Fish Consumption Advisory Protocols

Wisconsin has used protocols to help determine the appropriate consumption advice needed to protect health of fish eaters. Since 1997, Health Protection Values or safe intake amounts have been the basis for calculating fillet concentrations for standard fish meal frequencies (e.g. 1 meal per week) and used to provide advice designed to keep intake of toxic chemicals below those values. Health Protection Values (HPV) are determined for contaminants based on the health risks posed by the contaminant. A standard meal size is used and assumed proportional to the size of the person (1/2 pound of fish fillet before cooking for a 154 pound person). Wisconsin's current protocols and the health guidelines used for issuing advisories are listed in Table 3.

Concentrations of contaminants in the edible portions of a species are evaluated on site-by-site, reach-by-reach, and statewide bases. The resulting meal frequency becomes the consumption advice. Each year, the DNR reviews newly obtained contaminant data in the context of existing data and advisories. The DNR and DHS determine whether a sample is of public health significance. When concentrations exceed health guidelines, DNR and DHS jointly issue a fish consumption advisory for the appropriate water body. For the Great Lakes and border waters, fish contaminant data are shared and analyses are conducted in conjunction with other states.

While a one time sampling event may lead to

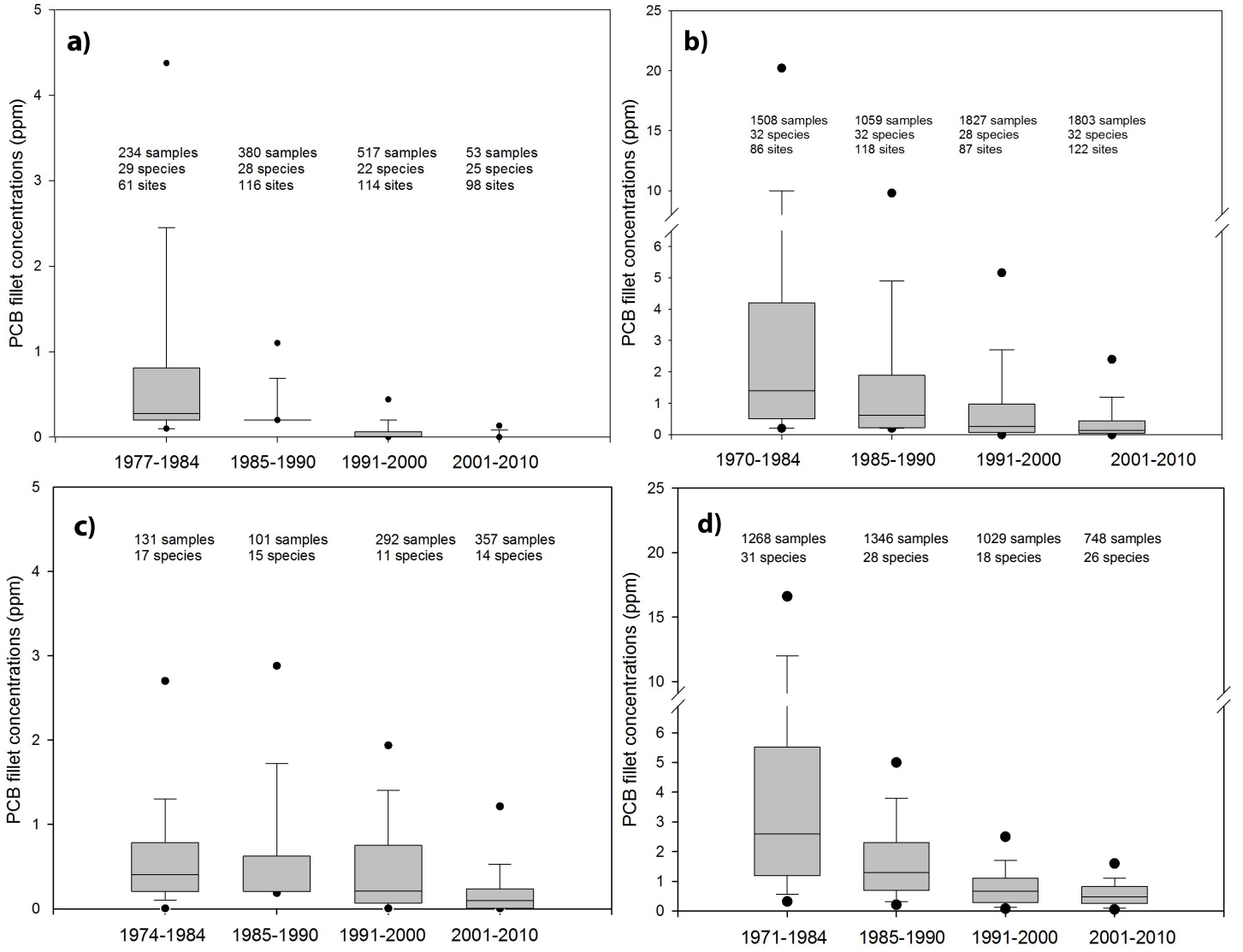

Figure 3. PCB concentrations in fish fillets from a) inland waters that contained low PCB concentrations (no advisories), b) inland waters containing high PCB concentrations (waters having consumption advisories), c) Lake Superior, and d) Lake Michigan and Green Bay. Note the change in scale: figures a) and c) display much lower concentrations than figures b) and d).

Table 3. Wisconsin fish consumption advisory protocols

Contaminant	Population	Concentration Range	Meal Frequency Recommendation
PCBs[1]	All	≤ 0.05 ppm	Unlimited consumption
		0.05 - 0.22 ppm	1 meal/week or 52 meals/year
		0.22 - 1.0 ppm	1 meal/month or 12 meals/year
		1.0 - 1.9 ppm	6 meals/year
		≥ 2 ppm	Do Not Eat
Mercury: General	Sensitive Group[2]	≤ 0.05 ppm	Unlimited consumption
		0.05 - 0.22 ppm	1 meal/week or 52 meals/year
		0.22 - 0.95 ppm	1 meal/month or 12 meals/year
		> 0.95 ppm	Do Not Eat
	Others[2]	≤ 0.16 ppm	Unlimited consumption
		0.16 - 0.65 ppm	1 meal/week or 52 meals/year
		> 0.65 ppm	1 meal/month or 12 meals/year
Mercury: Site-Specific	All	Species-site panfish average > 0.22 ppm (n > 4), max > 0.33 ppm Species-site gamefish average > 0.65 ppm, max > 0.95 ppm	Sensitive group: 1 meal/month of panfish, Do Not Eat gamefish General group: 1 meal/week of panfish, 1 meal/month of gamefish
Dioxin[3]	All	< 10 ppt	No advice given
		> 10 ppt	Do Not Eat
Chlordane[4]	All	< 0.16 ppm	No advice given
		0.16 - 0.65 ppm	1 meal/week or 52 meals/year
		0.66 - 2.82 ppm	1 meal/month or 12 meals/year
		2.83 - 5.62	6 meals/year
		> 5.62 ppm	Do Not Eat
PFOS[5]	All	< 38 ng/g	Unlimited consumption
		38 - 160 ng/g	1 meal/week or 52 meals/year
		160 - 700 ng/g	1 meal/month or 12 meals/year
		> 700 ng/g	Do Not Eat

[1]**PCBs -** Species-site specific advisories are provided to protect against reproductive health effects and other potential health effects such as immune suppression and cancer. The same advice is given for women, children, and men. The following values were used in deriving the fish tissue criteria for PCBs:

- Health Protection Value of 0.05 ug PCB/kg/day. Average Meal size = 227 g uncooked fish. Consumer = 70 kg adult for others, meal size is assumed proportional to body size). Meal rates defined in the advisory ranging from unrestricted (>225/yr) to none. Skinning/trimming/cooking reduction factor = 50%. The Health Protection Value is from the "Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory. Great Lakes Sport Fish Task Force. September 1993. Since 2000, only specific PCB-based advice is listed for species-sites more stringent than the general statewide advisory.

[2]**Mercury -** Sensitive group includes pregnant women, women of childbearing age, and children under age 15. Others are women beyond childbearing age and men. The HPV for the sensitive group is 0.1 µg/kg/day (EPA RfD) and for others it is 0.3 µg/kg/day (Iraq 1990 RfD). A Protocol for Mercury-based Fish Consumption Advice. Anderson et al., May 2007. Average Meal size = 227 g uncooked fish. Consumer = 70 kg adult (for others, meal size is assumed proportional to body size). Meal rates defined in the advisory ranging from unrestricted (>225/yr) to none. No reduction factor is applied.

- For the statewide general advisory, species were placed in a meal-category considering the distribution of concentrations for each species in the tissue criteria for each meal category, angler harvest, bag and size limitations, and other factors pertinent to consumption.
- In addition to the general advisory, mercury-based special advice is provided for species-sites where higher mercury concentrations have been documented. For special mercury advisories, a number of factors are examined including: maximum and average concentrations for a species in a waterbody or reach, concentration-size relationships, size range of the species expected to be harvested, angler harvest information, and other factors.

[3]Sum of total dioxin equivalence expressed as 2,3,7,8 TCDD based on dioxin and furan congeners and WHO 2005 human health TEFs

[4]Sum of chlordane isomers. Hornshaw 1999 HPV = 0.15 µg/kg/day

[5]MN Rfd (Seacat et al. 2002 Tox Sci 68:249-264) 0.075 µg/kg/day

the issuance of an advisory, levels of a particular contaminant must decline below the meal frequency range for at least two years (of sampling) within 5 consecutive years before advice for a particular species and location are relaxed. The contaminant with the most stringent meal advice is provided to the public where two or more contaminants are found in fish. Additive effects of multiple contaminants is not considered at this time except in evaluating dioxin toxicity.

Fish Contaminant Monitoring

The monitoring program consists of different components depending on the purpose of the monitoring (advisory, Great Lakes, or trend), the area of the state or the waterbody type (inland lakes, rivers, Great Lakes), and also varies depending on the contaminant (mercury, PCBs, pesticides, dioxin/furans, and emerging chemicals). Samples collected at new sites are primarily analyzed for mercury content but some samples are also analyzed for PCBs and other contaminants, especially those from flowing waters or impoundments located in industrial or urban areas. Samples collected at PCB advisory sites are primarily analyzed for PCBs and mercury content but a subset of samples are analyzed for dioxin/furan congeners, banned pesticides, and emerging chemicals.

In recent years, DNR collected fish for contaminant monitoring from approximately 30 to 70 sites each year. See Table 1 for a tally of the number of sites sampled and the number samples collected over the years (these values include sites and samples collected by cooperators). DNR tests about 600 samples for mercury, 350 for total PCBs, 30 for banned pesticides, 20 for dioxin/furan analysis and 10 for other substances each year. Collection of fish is achieved through fieldwork conducted for fisheries management surveys to allow savings in field costs.

Mercury monitoring focuses on lakes that have not been sampled, sites where contaminant data is old (more than 15 years old) or limited, or where existing data shows that concentrations may be high and additional data would be beneficial to determine advisory needs. In general, samples of a top-level predator species and a panfish species are collected. Additional species may be collected depending on the site characteristics and availability of past contaminant data and existing advisories for the specific waterbody. Most samples are analyzed as edible portions (i.e. fillets) unless trend data need to be maintained. The goal is to return to sites with suspected high mercury concentrations every 10 to 15 years or when fisheries management schedules allow more frequent monitoring. Samples may be taken to fill in data gaps as opportunities arise.

Monitoring at inland sites with PCB based fish consumption advice generally occurs on a five year rotating basis. Species are chosen based on data gaps and advisories for the site, angler survey data, availability of species, desire to maintain consistency with past collections, and regulations for a specific waterbody.

Great Lakes and Mississippi River fish contaminant monitoring is conducted on a biennial basis. The collection schedule includes both gamefish and forage fish from Lakes Superior and Michigan and the Mississippi River; salmonid species biennially from Lake Michigan and Green Bay; alewife and bloater chubs from these same areas. The collection schedule includes lean lake trout, siscowet lake trout, sculpins, and herring from the open waters of Lake Superior and walleyes from tributary areas along Lake Superior.

In addition, the DNR has cooperated with the EPA Great Lakes National Program Office since the late 1980s to determine trends and patterns of contaminant levels in key salmon species. The DNR participates in this monitoring by collecting fish, processing samples, and shipping samples as defined in inter-agency agreements. This includes collection of coho or Chinook salmon at three Great Lakes tributaries, until 2009, and lake trout, ongoing, from Lake Superior every other year.

Data Summaries

Table 1 shows a summary of the number of sites sampled and fish samples collected by the DNR and others and stored in the DNR Fish Contaminant Database (1970 to 2010 results verified as of fall 2011). Figures 3 and 4 show the total PCB and mercury fillet concentrations (1970-2010) of all species by different groups of waters (inland, high advisory, and Great Lakes). Appendix I lists the parameters quantified in fish samples between the years 1970-2010.

Contaminant data are stored in the DNR's fish-sediment contaminant database consisting of a series of Oracle tables and managed on a client-server system. The Fish-Sediment Contaminant

Database contains the results, associated sample, and site information. Data are available upon request after field verification and DNR analyses are completed. Verified data are also available to other agencies and the public upon request specifying the desired collection dates, geographical area, species and form of fish, and parameters.

Recent Developments

Trends Over time and Geographically

Recently, Rasmussen et al. (2007) found that mercury concentrations in walleye from Wisconsin's inland lakes increase with the size or age but that relationship varied among lakes (See Figure 5). Mercury concentrations in walleye fillets were related to latitude, with higher concentrations found in northern lakes versus more southern lakes. Mercury concentrations in lake walleye changed over time from 1982 to 2005, decreasing 0.5% per year in northern lakes and increasing 0.8% per year in southern lakes (see Figure 6). Other factors found to affect mercury concentrations included gender, lake area, season, and total alkalinity of lake water. Monson et al (2011) also found that mercury concentrations in fillets declined in walleye and largemouth bass using data from Wisconsin and the broader area of the Great Lakes region (1970-2009). Spatially, concentrations were generally higher in the northern and eastern parts of the Great Lakes region.

Awareness and Effectiveness

Surveys of awareness indicate whether messages about consumption advice reach people who eat fish. Awareness surveys have

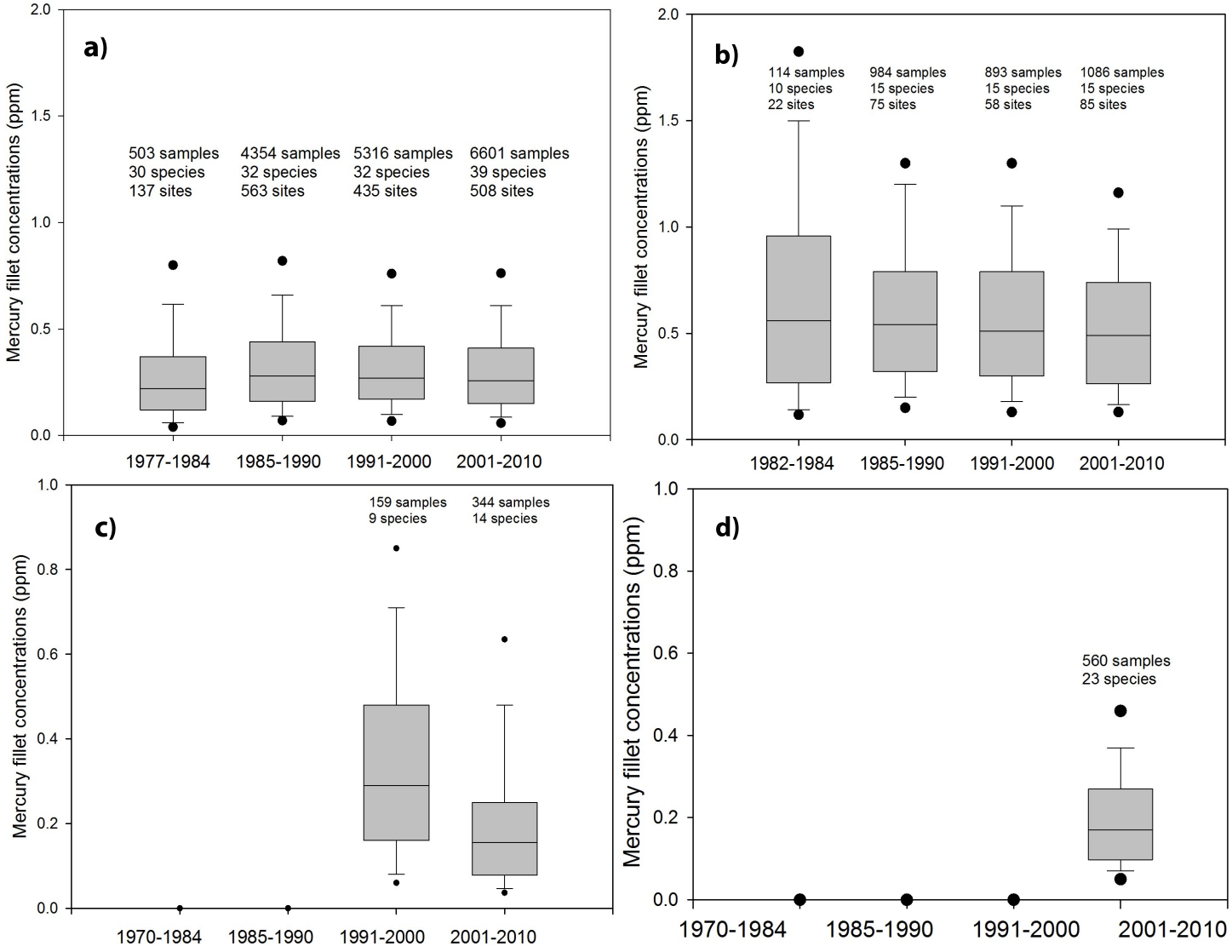

Figure 4. Mercury concentrations in fish fillets from a) inland waters that contained low mercury levels (no advisories), b) inland waters containing high mercury levels (waters having consumption advisories), c) Lake Superior, and d) Lake Michigan and Green Bay.

changed over time, first using simple questions about awareness and later asking more sophisticated questions like sources of information, comprehension of and adherence to advice. Surveys have focused on different population cohorts (e.g. Great Lakes anglers, mothers recently giving birth, randomly selected participants). Based on a statewide survey conducted in 2004, 78% of adults living in Wisconsin had heard about the need to limit consumption of certain types of fish because of mercury contamination. Awareness rates vary by race being highest among Native Americans and white residents. Awareness increases with household income and educational attainment. Through these surveys, it appears news coverage and 'word of mouth' reaches more people. Advisory information presented by DHS and DNR is via a variety of routes including printed booklets and brochures (some in Spanish and Hmong in addition to English), websites, the fishing regulations booklet, regular press releases and other media.

Human Biomonitoring In Wisconsin

Based on national studies, 83% of Wisconsin adults eat fish and shellfish (includes both purchased and caught fish). The average number of meals consumed is 4 to 6 meals per month. One way to measure effectiveness of clean-up actions and advisory efforts is to track human exposures. Recent studies determined that exposure to PCBs and DDE (a metabolite of the banned pesticide DDT) have decreased in a cohort of frequent sportfish consumers (primarily Great Lakes Charter boat captains and anglers) since 1993. The lower blood PCB levels reflect both cleaner fish and a change in consumption patterns.

Mercury exposure among Wisconsin residents was recently assessed using hair samples provided by 2031 volunteers. Among the hair donors, who were somewhat more likely to consume fish than the general population, mercury levels ranged form 0.012 to 15.2 μg/g (ppm). Levels exceeded the hair guideline of 1 ppm in 29% of men and 13% of women who participated. Average hair mercury was higher in men (0.918 ppm) than in women (0.525 ppm) and levels were significantly correlated with monthly fish consumption estimates.

DHS and DNR staff recently documented case studies of 14 individuals who were concerned about their mercury exposure. Frequency and types of fish ingested were investigated and estimated averages varied up to about nine

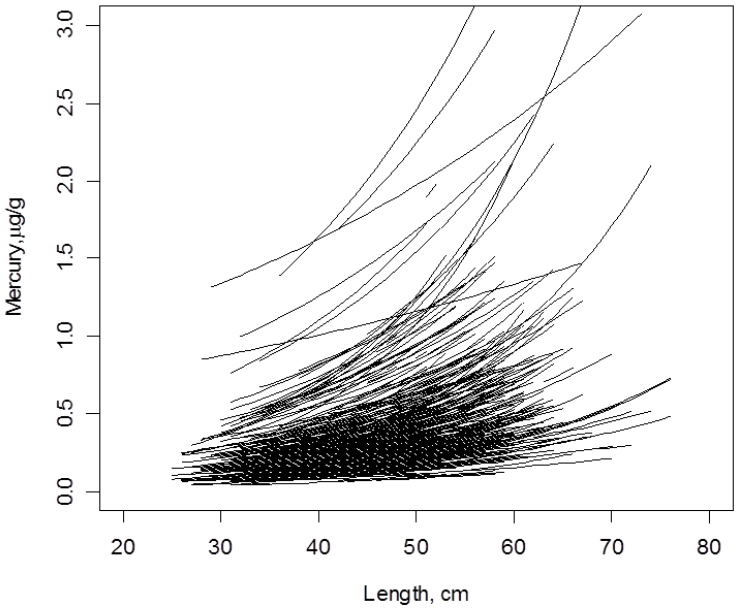

Figure 5. Mercury concentrations in skin-on walleye fillets compared to length for 421 inland lakes. Data is from Rasmussen et al. 2007.

meals per week. Steady-state blood mercury levels in 11 individuals ranged from < 5 to 58 μg/L and correlated well with dietary mercury intake from fish. Three of these individuals reported vague, sub-clinical symptoms such as mental confusion, sleep difficulty, balance problems or visual disturbances that improved after their mercury levels returned to normal.

Health Effects

Mercury poisonings in Japan and Iraq during the 1950s, 60s, and 70s brought world attention to the bioavailability, bioaccumulation and toxicity of methylmercury. More recent studies have focused on the development of children of mothers who regularly consume fish containing mercury. Effects on the developing brain and nervous system are generally accepted to represent the most sensitive end-point from exposure to methylmercury. However, several recent studies suggest that methylmercury may also play a role in the development of cardiovascular disease. A study of Finnish fishermen found that men whose hair mercury levels exceeded 2 μg/g were twice as likely to suffer a heart attack during the subsequent seven years compared to men with lower mercury levels (Salonen et al 1995). Later studies have confirmed this effect suggesting that adult men and older women are also at risk of mercury-induced health problems. These and potentially other studies may continue to refine this information.

Benefits of Eating Fish

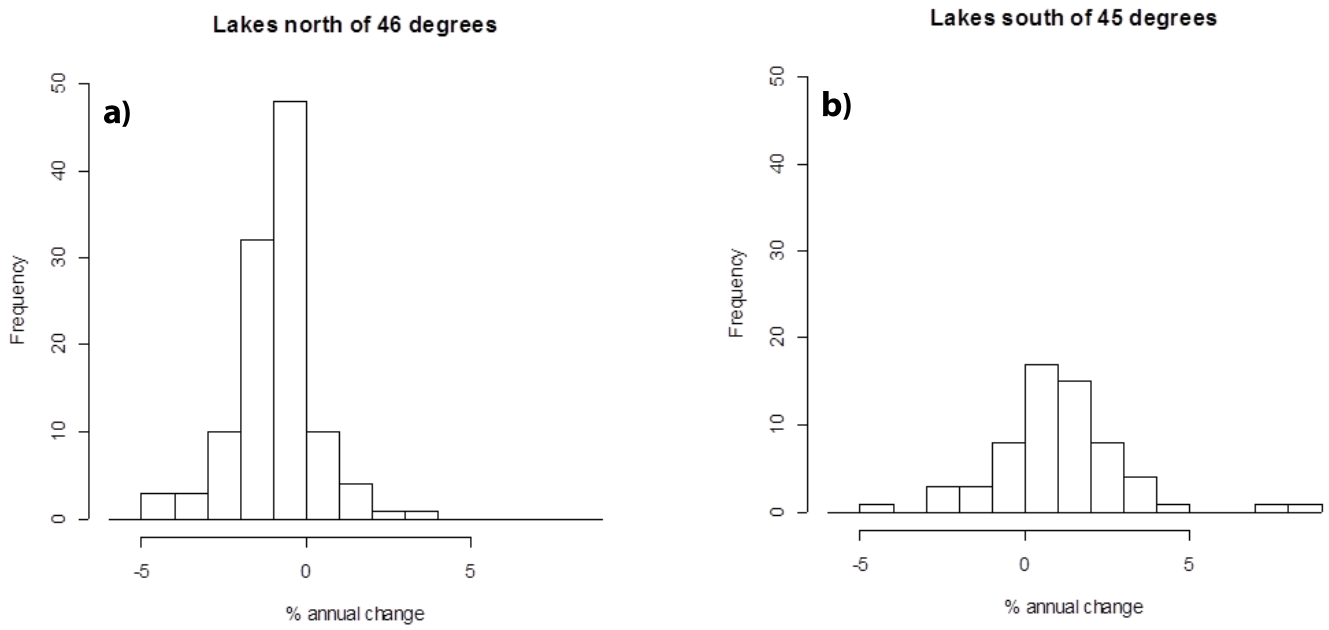

Figure 6. Distribution of change in mercury in walleye fillets: a) north of 46° latitude, showing a mercury concentration decrease at a rate of 0.5% per year and b) south of 46° latitude, showing a mercury concentration increase at a rate of 0.8% per year.

Fish can be part of a healthy, balanced diet. Fish are generally low in saturated fat and high in protein. Fish contain a number of vitamins and minerals, and are the primary food source for omega-3 fatty acids. Studies suggest that omega -3 fatty acids may be beneficial during fetal brain and eye development, and modest consumption of fish containing omega-3s may lower the risk of heart disease in adults. Health experts recommend that regular consumption of fish be included as part of a healthy diet. New studies suggest that the majority of benefits is achieved with modest fish consumption (one or two 4-6 oz servings per week) and may outweigh the risks to adults especially when high contaminant fish are avoided. The American Heart Association recommends at least two fish meals per week.

Program Resources

The fish contaminant monitoring and advisory activities has been supported by a variety of resources and has changed over the years. Where possible, fish collections are conducted in conjunction with fisheries management activities to minimize field costs and equipment needs. Most of DNR's fish tissue samples are analyzed on a non-fee basis by the Wisconsin State Laboratory of Hygiene. Federal funds support management of the monitoring and advisory program and processing and storage of fish samples. Analysis of some chemicals requires contracting with private laboratories. Federal funds also support in part DNR outreach and communication materials and programs.

Fish advisory information is communicated to the public in several ways, including websites (http://dnr.wi.gov/topic/Fishing/Consumption/ and http://dhs.wisconsin.gov/eh/fish/), publications like the Fishing Regulations booklet available to licensed anglers, advisory booklets available on request and through local DHS and DNR offices, and annual fishing reports, and also through annual or occasional press releases distributed to media sources.

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Appendix I. List of parameters quantified in fish samples analyzed 1970 - 2010.

Parameter Code	Parameter Name	Count	Parameter Code	Parameter Name	Count	Parameter Code	Parameter Name	Count
#101	PCB Congener #101	291	#206	PCB Congener #206	290	#95	PCB Congener #095	31
#105/132	PCB Congener #105/132/153	31	#207	PCB Congener #207	31	#97	PCB Congener #097	291
#118	PCB Congener #118	311	#22	PCB Congener #022	291	#99	PCB Congener #099	291
#123/149	PCB Congener #123/149	31	#24/27	PCB Congener #024/027	291	2,4-D	2,4-D	3
#132/153	PCB Congener #132/153	250	#25	PCB Congener #025	31	41,64,71	PCB Congener #041/064/071	291
#135/144	PCB Congener #135/144	291	#26	PCB Congener #026	291	ACENAPHT	Acenaphthene	43
#136	PCB Congener #136	291	#28/31	PCB Congener #028/031	291	ACENATHY	Acenaphthylene	43
#137/176	PCB Congener #137/176	291	#3	PCB Congener #003	31	ALDRIN	Aldrin	1070
#138/163	PCB Congener #138/163	291	#33	PCB Congener #033	291	ALPHABHC	Alpha BHC	936
#141	PCB Congener #141	291	#37/42	PCB Congener #037/042	291	ANTHRACE	Anthracene	43
#146	PCB Congener #146	291	#4/10	PCB Congener #004/010	31	ARSENIC	Arsenic	1507
#149	PCB Congener #149	250	#40	PCB Congener #040	291	BENZOAAN	Benzo (A) Anthracene	43
#15/17	PCB Congener #015/017	31	#44	PCB Congener #044	291	BENZOAPY	Benzo (A) Pyrene	43
#151	PCB Congener #151	291	#45	PCB Congener #045	291	BENZOBFL	Benzo (B) Fluoranthene	43
#158	PCB Contener #158	31	#46	PCB Congener #046	291	BENZOEPY	Benzo (E) Pyrene	7
#16/32	PCB Congener #016/032	291	#47/48	PCB Congener #047/048	291	BENZOGHI	Benzo (G H I) Perylene	43
#167	PCB Congener #167	6	#49	PCB Congener #049	291	BENZOKFL	Benzo (K) Fluoranthene	43
#17	PCB Congener #017	250	#5/8	PCB Congener #005/008	291	CADMIUM	Cadmium	1565
#170/190	PCB Congener #170/190	291	#51	PCB Congener #051	31	CHLORD-C	Cis-Chlordane	3467
#171/202	PCB Congener #171/202	281	#52	PCB Congener #052	291	CHLORD-T	Trans-Chlordane	3327
#172	PCB Congener #172	31	#53	PCB Congener #053	31	CHLORDNC	Cis-Nonachlor	3232
#172/197	PCB Congener #172/197	250	#56/60	PCB Congener #056/060	291	CHLORDNT	Trans-Nonachlor	3185
#174	PCB Congener #174	291	#6	PCB Congener #006	291	CHROMIUM	Chromium	1575
#177	PCB Congener #177	291	#63	PCB Congener #063	31	CHRYSENE	Chrysene	43
#178	PCB Congener #178	281	#66	PCB Congener #066	31	COPPER	Copper	1609
#18	PCB Congener #018	281	#66/95	PCB Congener #066/095	250	D1234678	1,2,3,4,6,7,8-HpCDD	191
#180	PCB Congener #180	294	#7	PCB Congener #007	259	D27MNAPH	2,7-Dimethylnaphthalene	7
#182/187	PCB Congener #182/187	291	#7/9	PCB Congener #007/009	31	DDD-OP	OP-DDD	2614
#183	PCB Congener #183	291	#70/76	PCB Congener #070/076	291	DDD-PP	PP-DDD	2740
#185	PCB Congener #185	281	#74	PCB Congener #074	291	DDE-OP	OP-DDE	2605
#19	PCB Congener #019	291	#77/110	PCB Congener #077/110	291	DDE-PP	PP-DDE	3136
#193	PCB Congener #193	31	#82	PCB Congener #082	290	DDT-OP	OP-DDT	2610
#194	PCB Congener #194	291	#83	PCB Congener #083	31	DDT-PP	PP-DDT	2708
#195/208	PCB Congener #195/208	291	#84/92	PCB Congener #084/092	281	DIBENZAH	Dibenzo (A H) Anthracene	43
#196/203	PCB Congener #196/203	291	#85	PCB Congener #085	291	DIELDRIN	Dieldrin	3607
#198	PCB Congener #198	31	#87	PCB Congener #087	291	DX123478	1,2,3,4,7,8-HxCDD	191
#199	PCB Congener #199	291	#89	PCB Congener #089	31	DX123678	1,2,3,6,7,8-HxCDD	191
#201	PCB Congener #201	291	#91	PCB Congener #091	291	DX12378	1,2,3,7,8-PeCDD	191

Appendix I (cont'd). List of parameters quantified in fish samples analyzed 1970 - 2010.

Parameter Code	Parameter Name	Count
DX123789	1,2,3,7,8,9-HxCDD	191
ENDRIN	Endrin	1204
F1234678	1,2,3,4,6,7,8-HpCDF	191
F1234789	1,2,3,4,7,8,9-HpCDF	191
FAT	% FAT	16811
FLUORANT	Fluoranthene	43
FLUORENE	Fluorene	43
FR123478	1,2,3,4,7,8-HxCDF	191
FR123678	1,2,3,6,7,8-HxCDF	191
FR12378	1,2,3,7,8-PeCDF	191
FR123789	1,2,3,7,8,9-HxCDF	190
FR234678	2,3,4,6,7,8-HxCDF	191
FR23478	2,3,4,7,8-PeCDF	191
GAMMABHC	Gamma BHC	1068
HEPCH-EP	Heptachlor epoxide	56
HXCHLBNZ	Hexachlorobenzene	1098
ICPQSCAN	ICP Qualitative Scan	51
INDENO12	Indeno (1,2,3-C D) Pyrene	43
LEAD	Lead	1574
MERCURY	Mercury	23220
MET2NAPH	2-Methylnaphthalene	7
METHXYCL	Methoxychlor	1139
MTH1NAPH	1-Methylnaphthalene	7
NAPHTHAL	Naphthalene	43
OCDD	1,2,3,4,6,7,8,9-OCDD	191
OCDF	1,2,3,4,6,7,8,9-OCDF	191
PBDE100	PBDE #100	77
PBDE138	PBDE #138	77
PBDE153	PBDE #153	77
PBDE154	PBDE #154	77
PBDE28	PBDE #28	77
PBDE47	PBDE #47	77
PBDE66	PBDE #66	77
PBDE85	PBDE #85	77
PBDE99	PBDE #99	77
PCB	PCB	16405
PCB#105	PCB Toxic Congener #105	161
PCB#114	PCB Toxic Congener # 114	13
PCB#123	PCB Toxic Congener #123	140
PCB#126	PCB Toxic Congener #126	161
PCB#128	PCB Toxic Congener #128	261
PCB#156	PCB Toxic Congener #156	140
PCB#157	PCB Toxic Congener #157	140
PCB#167	PCB Toxic Congener #167	264
PCB#169	PCB Toxic Congener #169	165
PCB#170	PCB Toxic Congener #170	3
PCB#189	PCB Toxic Congener #189	13
PCB#77	PCB Toxic Congener #077	161
PCB#81	PCB Toxic Congener #81	4
PCP	Pentachlorophenol	943
PFBA	PFC PFBA	57
PFBS	PFC PFBS	57
PFDA	PFC PFDA	19
PFDOA	PFC PFDoA	19
PFDS	PFC PFDS	38
PFHPA	PFC PFHpA	19
PFHPS	PFC PFHpS	38
PFHXA	PFC PFHxA	57
PFHXS	PFC PFHxS	57
PFNA	PFC PFNA	19
PFOA	PFC PFOA	57
PFOS	PFC PFOS	57
PFOSA	PFC PFOSA	19
PFPEA	PFC PFPeA	57
PFUNA	PFC PFUnA	19
PHENANTH	Phenanthrene	43
PNCRANIS	Pentachloroanisol	12
PYRENE	Pyrene	43
SELENIUM	Selenium	131
SILVER	Silver	44
SOLIDS %	Solids - Percent	19
T HPCDD	Total HpCDDs	120
T HPCDF	Total HpCDFs	120
T HXCDD	Total HxCDDs	120
T HXCDF	Total HxCDFs	120
T PECDD	Total PeCDDs	120
T PECDF	Total PeCDFs	120
T TCDD	Total TCDDs	120
T TCDF	Total TCDFs	120
TCDD2378	2378TCDD	445
TCDF2378	2378TCDF	380
TCP245	2,4,5 trichlorophenol	81
TCP246	2,4,6 trichlorophenol	81
TEMPLAB	Temperature at Lab	1
TOXAPHEN	Toxaphene-like compounds	299
ZINC	Zinc	161